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PLASTICITY OF FINE REFRACTORIES MIXES FROM INDUSTRIAL CERAMICS LIMITED

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PLASTICITY OF FINE REFRACTORIES MIXES FROM INDUSTRIAL CERAMICS LIMITED

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ABSTRACT

At the request of Industrial Ceramics Limited, Mississauga, Ontario, a series of fine refractories compositions were examined using the Brabender Plastograph. The work was conducted under Mineral Sciences Laboratories Cost Recovery Job 025268.

Owing to the high densities of many of the constituents, the standard test procedure required modification; 400 g aliquots (instead of 200 g) were used. Interpretation of the results was therefore based on CANMET experience, with reference to the results obtained using the company's regular production mixture, which has been refined empirically over several years to produce excellent results in all processing aspects.

Pursuant to discussion of the results obtained on the initial suite of 6 samples, a further 7 samples of modified compositions, other production mixes and proposed production formulations were evaluated.

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INTRODUCTION

Industrial Ceramics Limited, Mississauga, Ontario, produces a variety of fine refractory products by slip-casting, dry pressing, isostatic pressing. However, the bulk of production, principally for export, comprises refractory ferrules for protecting the combustion-zone end of metal fire-tube boilers, and is produced by extrusion of blank tubes that are machined in the leather-hard condition to the desired external configuration. Mr. J. Foster, Ceramic Engineer, requested CANMET to examine the plastic behaviour of a number of compositions from current production, proposed formulations and component materials, using the Brabender Plastograph.

The work was performed under Project 3.0.2.9.99, Cost Recovery-Ceramics, Job No. 025268.

MATERIALS

All compositions were provided as dry flours, quartered from mixed batches of substantial size. A suite of 6 test batches was supplied initially. Pursuant to advice as to their behaviour, two further suites, of 4 and 3 test batches respectively, were provided for examination.

The samples were identified by Industrial Ceramics Ltd. as:

Suite I:	Batch #1 (Regular production mix)
	Batch #2
	Batch #3
	Batch #4
	Batch #5
	Batch #6
Suite II:	Batch #1M (Regular mix with Huntington clay)
	Batch #4M (#4, modified)
	Batch #5M (#5, modified)
	Batch #7 (Zircon Special)
Suite III:	Batch #8 (90% Alumina mix)
	Batch #9 (No. 6 Tile clay)
	Batch #10 (Zircon/Mullite)

PROCEDURE

The procedure standard to this laboratory required modification to cope with these materials. Because of the high densities of the constituents of the mixtures (zirconia, zircon, alumina), the standard sample of 200 grams mass did not sufficiently fill the mixer of the instrument, producing erroneous plasticity curves. The charge was increased to 400 grams: other parameters were unchanged, i.e., operated at "slow" speed, rate of water addition 0.5% per minute.

As a result of this change, the plastograms obtained cannot be directly compared with those in CANMET's data bank. However, Batch #1 (regular production mix) is known to perform excellently from the standpoint of both extrusion and subsequent machining, hence forms a most acceptable basis for comparison.

RESULTS AND DISCUSSION

The plastogram for Batch #1 is given in Fig. 1. The curve shows a moderately rounded peak of 1320 m.g of torque at 9% water. It can be deduced that a peak height of 1000 to 1100 m.g is adequate for good extrusion of thin-webbed hollow ware, and is also indicative of sufficient strength for machining in the semi-dry condition. The peak above this level is sufficiently broad and low to indicate ease of manual control of water content during continuous extrusion without excessive fluctuation of consistency (stiffness).

Batch #1M, also shown in Fig. 1, is reported to be equivalent to Batch #1, but with Huntington clay substituted for the regular clay. The plastogram shows a significantly sharper peak of 1410 m.g at 10% water content, apparently superimposed on a very broad peak at about 1000 m.g. The precise height and configuration of the superimposed peak is uncertain, as the material balled-up

and rode above the mixer blades giving rise to wide fluctuations in the indicated consistency. Very sharp, high-rising superimposed peaks of this type have been shown to be associated with the presence of pseudoplastic fine-grained non-clay constituents, in which case they lead to laminar flow that can adversely affect the quality of the tiles and could cause problems during semi-dry machining operations. In the case of Batch 1M, however, the rising slope of the peak is not near-enough vertical to indicate dilatency and the behaviour of the paste (sticking and balling) suggests the presence of highly plastic clay, perhaps montmorillonite. The narrow peak above 1000 to 1100 m.g would render manual control of the pugging water difficult.

Batch #2 (Fig. 2) shows a peak height of 1150 m.g at about 7.5% water content, considered sufficient for good extrusion and successful semi-dry machining. The peak is broad, indicating ease of manual control of pugging.

The plastogram for Batch #3 is also shown in Fig. 2. The curve is similar to that for Batch #1M, described above. The consistency rises to 1460 m.g in a narrow superimposed peak. (In this case, the peak is well-defined: the material did not appreciably ball-up in the mixer). The peak is amply broad at the 1000 to 1100 m.g level, but variations in moisture content over the indicated range would give rise to some changes in consistency, which could affect the uniformity of properties of the extruded column, although probably within acceptable levels.

Batch #4 (Fig. 3) produces a very sharp, high-rising peak that reaches 1580 m.g at 8.5% water content. The peak width at the desired level of 1000 to 1100 m.g is about 2% water addition, sufficient for adequate control of pugging, but in this case minor variation in water content would result in significantly affecting the uniformity of the column.

The attempt to modify Batch #4 (Batch #4M, Fig. 3) has served only to exacerbate the problems identified above. The sharply peaking plastogram is

plotted inversely here, as it rises to 2040 m.g (and may indeed be more, as this is beyond the maximum calibrated capacity of the instrument). Changes in formulation to broaden, rather than increase the height of the peak are desirable.

The plastogram for Batch #5 is given in Fig. 4. The curve shows a desirably broad peak configuration, but reaches a consistency level of only 700 m.g of torque, well below the desirable level established by Batch #1. It could be expected that thin-wall tile would be subject to cross-cracking during extrusion, and further cracking or severe straining during subsequent machining in the semi-dry state.

The formula modification (Batch #5M, Fig. 4) has successfully raised the consistency to acceptable levels it produced a high-rising superimposed peak reaching 1390 m.g at 7% water content. The plastogram is similar to that for Batch #3 and the same comments apply.

The plastogram for Batch #6 is given in Fig. 5. The curve is again of the most desirable, broad configuration, but reaches a peak of only 900 m.g at 7% water. Some cross-cracking of thin tile might be expected during extrusion. It should be borne in mind that the Plastograph measures, essentially, resistance to shear of the material by the mixer blades, an action similar to that of the machining stage of production. Based on Batch #1, it has been assumed that a plastograph peak in the range of 1000 to 1100 m.g is required to ensure adequate strength for machining in the leather-hard state. Hence products from Batch #6 might be expected to suffer damage during machining.

The plastogram for Batch #7 (Zircon Special) is also given in Fig. 5. The curve shows a broad, evenly proportioned curve reaching a moderately rounded peak of 1270 m.g at 9% water content. The curve is similar to, and only slightly lower than that for Batch #1, the performance standard, and excellent forming and machining properties would be expected.

Batch #8 (90% Alumina mix, Fig. 6) shows an unusually broad curve with a uniform, low upslope, indicative of easy wetting and plasticizing of the constituents, which are presumably fine-grained alumina with a modicum of (apparently) well-crystallized kaolin. The peak reaches 1200 m.g at 10% water content. Above the minimum postulated desirable level of 1000 m.g, the peak is amply broad for good manual control of the pugging process, with little change in consistency. Similarly, acceptable machining performance should be obtained.

The plastogram for Batch #9 (No. 6 Tile Clay) is also shown in Fig. 6. This is a moderately plastic clay, the curve reaching a peak of 890 m.g at 9% water. This is not a highly plastic (ball clay) material: from its name, one would expect it finds its primary use in dry-pressed tile production. It might possibly be useful in some of the other formulations as it may assist in reducing the sharpness of the superimposed peaks and thus aid in production of a more uniform extruded column, provided that its chemical composition is such as not to adversely affect the refractoriness of the products.

The plastogram of Batch #10 (Zircon/Mullite) is shown in Fig. 7. Again the upper portion of the curve is plotted inversely, as it rose to an estimated 2040 m.g of torque, beyond the calibrated capacity of the instrument. Again also, the exact configuration of the curve above about 1650 m.g is uncertain as the material balled-up and rode above the mixer blades: the curve may in fact rise much higher and be much sharper than indicated. Extrusion of this material is likely to require significantly greater power than any of the other Batches. It is recommended that the body be modified to reduce its plasticity. This might be accomplished by use of a less plastic, well crystallized kaolin component.

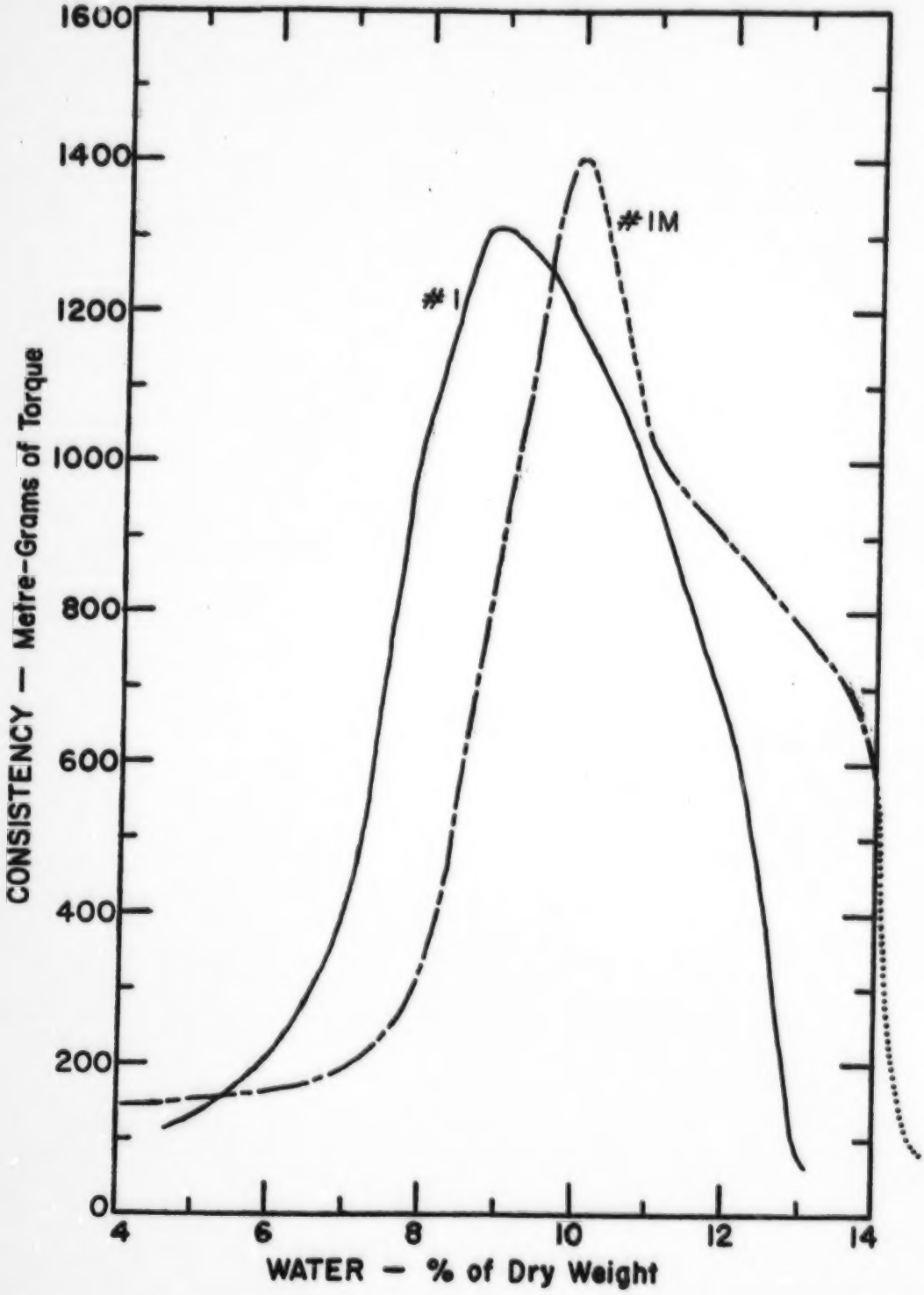

Fig. 1. Plastograms of test batches #1 (Regular Mix) and #1M (Regular + Huntington clay).

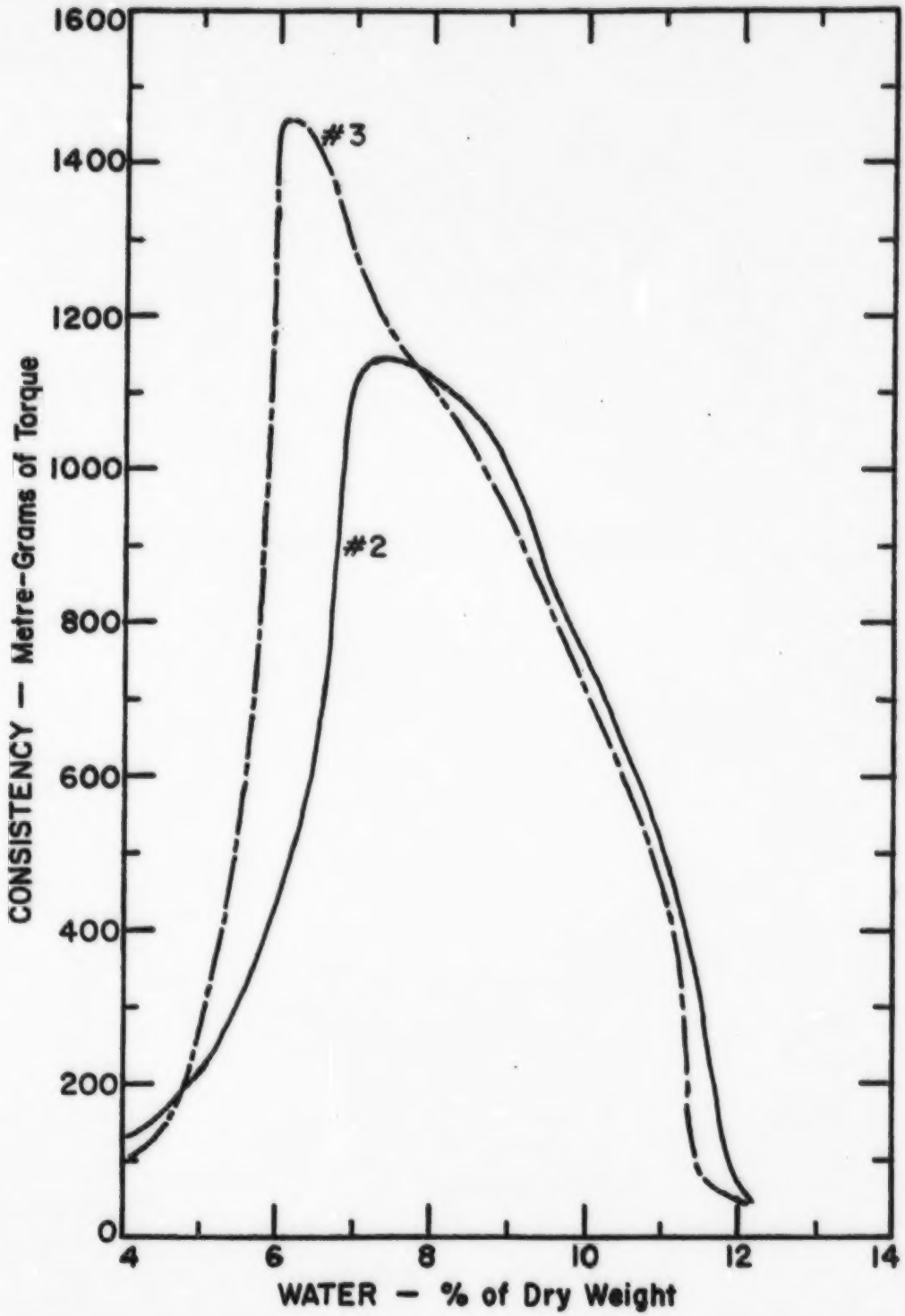

Fig. 2. Plastograms of test batches #2 and #3.

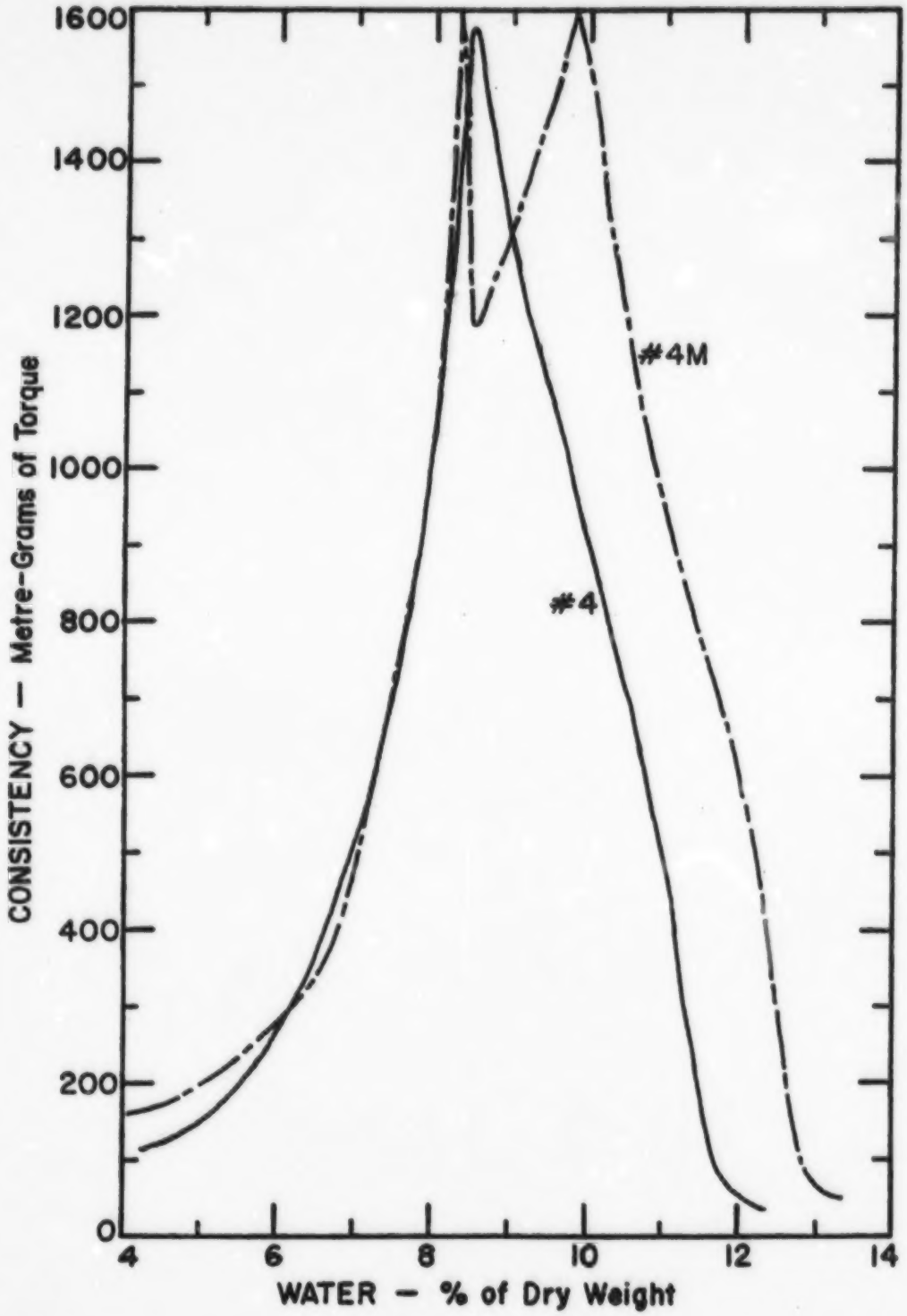

Fig. 3. Plastograms of test batches #4 and #4M.

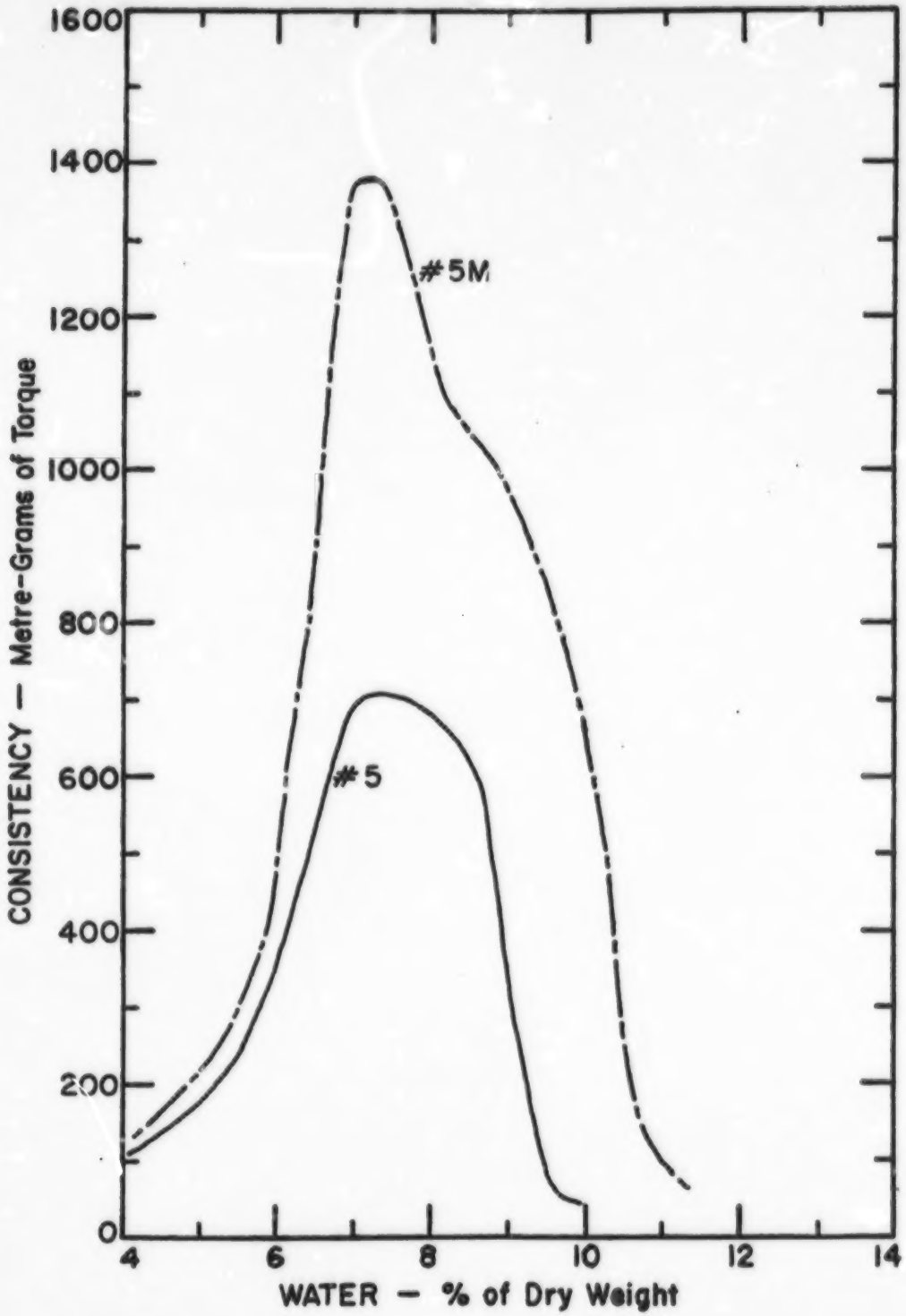

Fig. 4. Plastograms of test batches #5 and #5M.

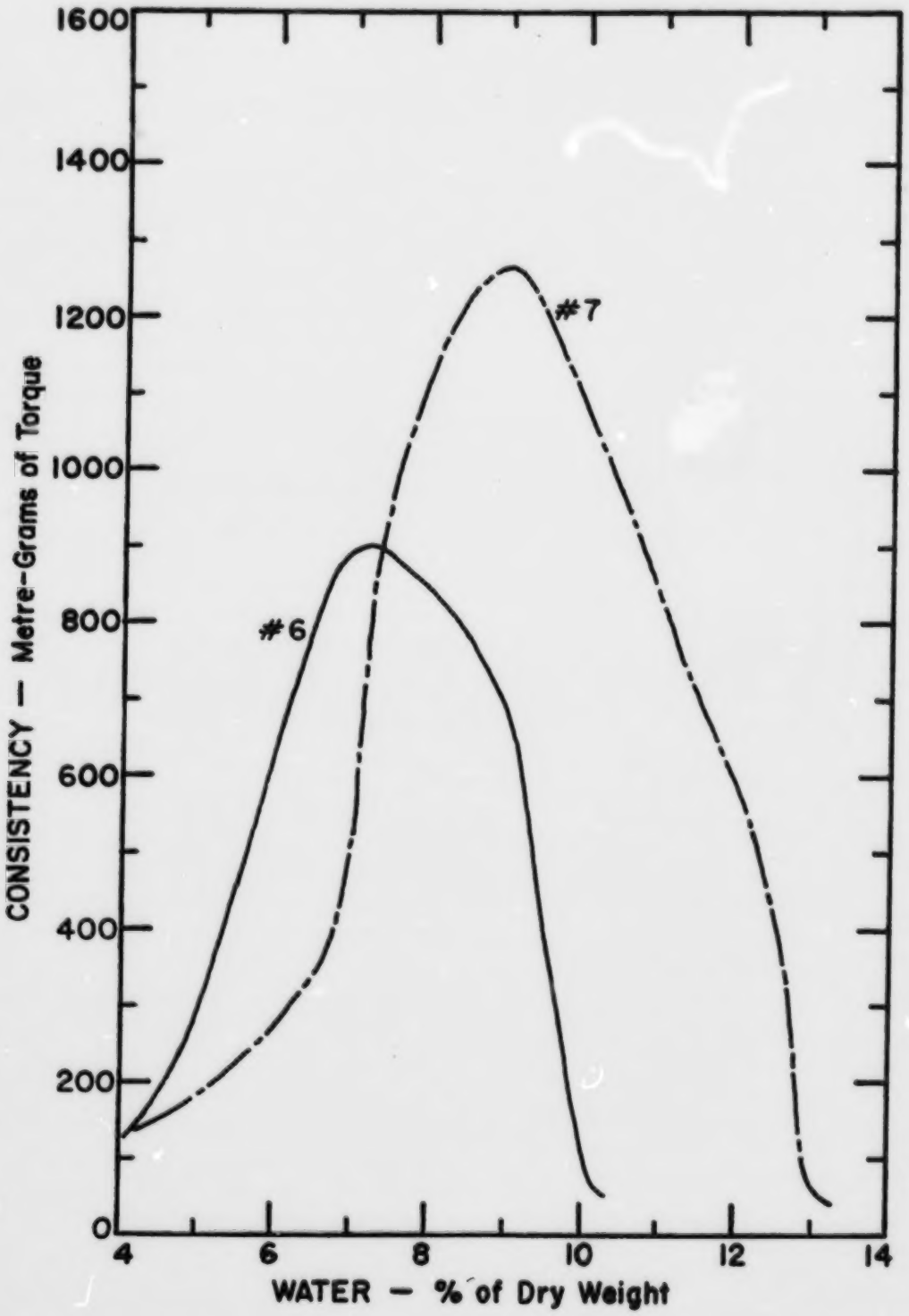

Fig. 5. Plastograms of test batches #6 and #7 (Zircon Special).

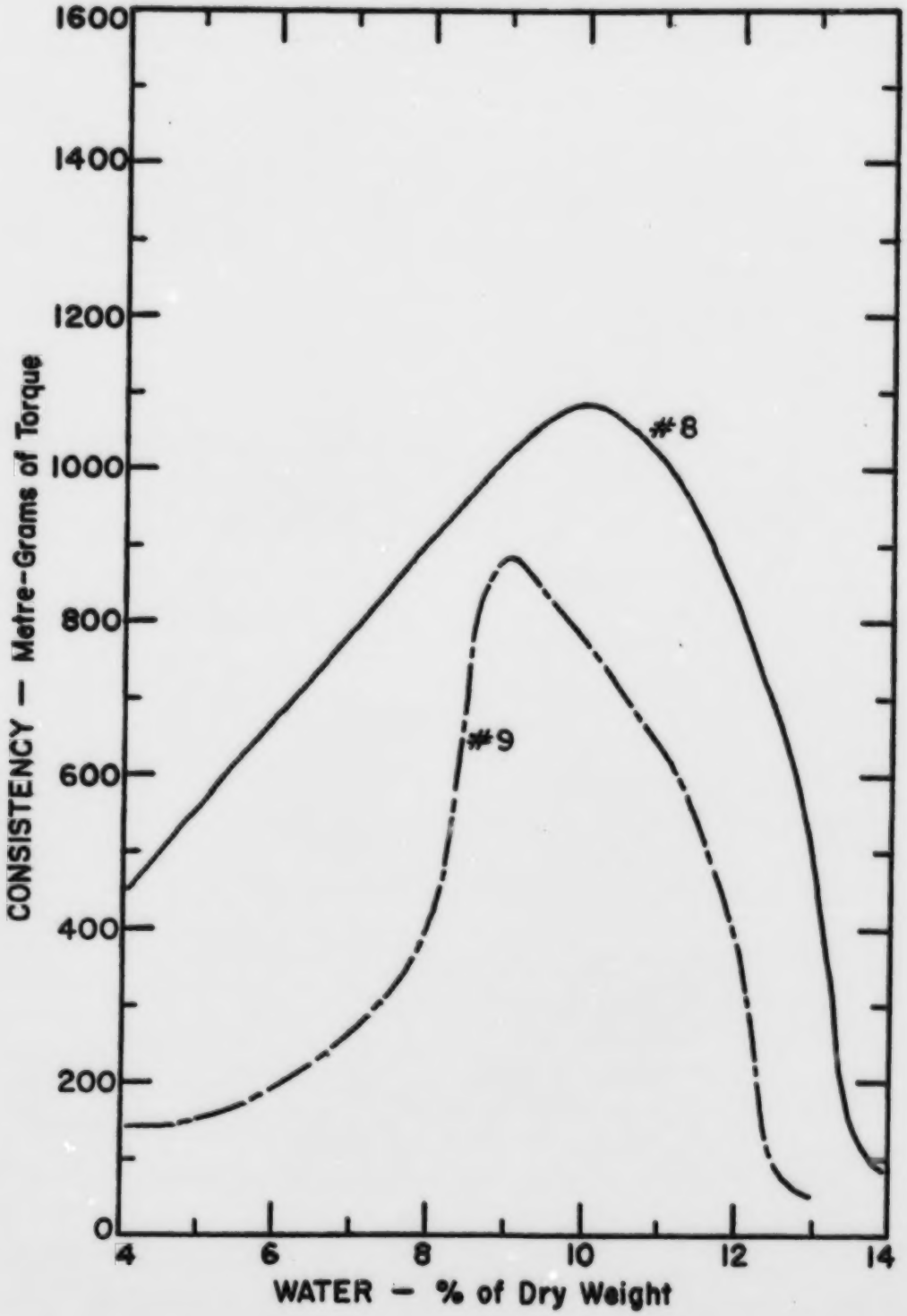

Fig. 6. Plastograms of test batches #8 (90% Alumina Mix) and #9 (No. 6 Tile Clay).

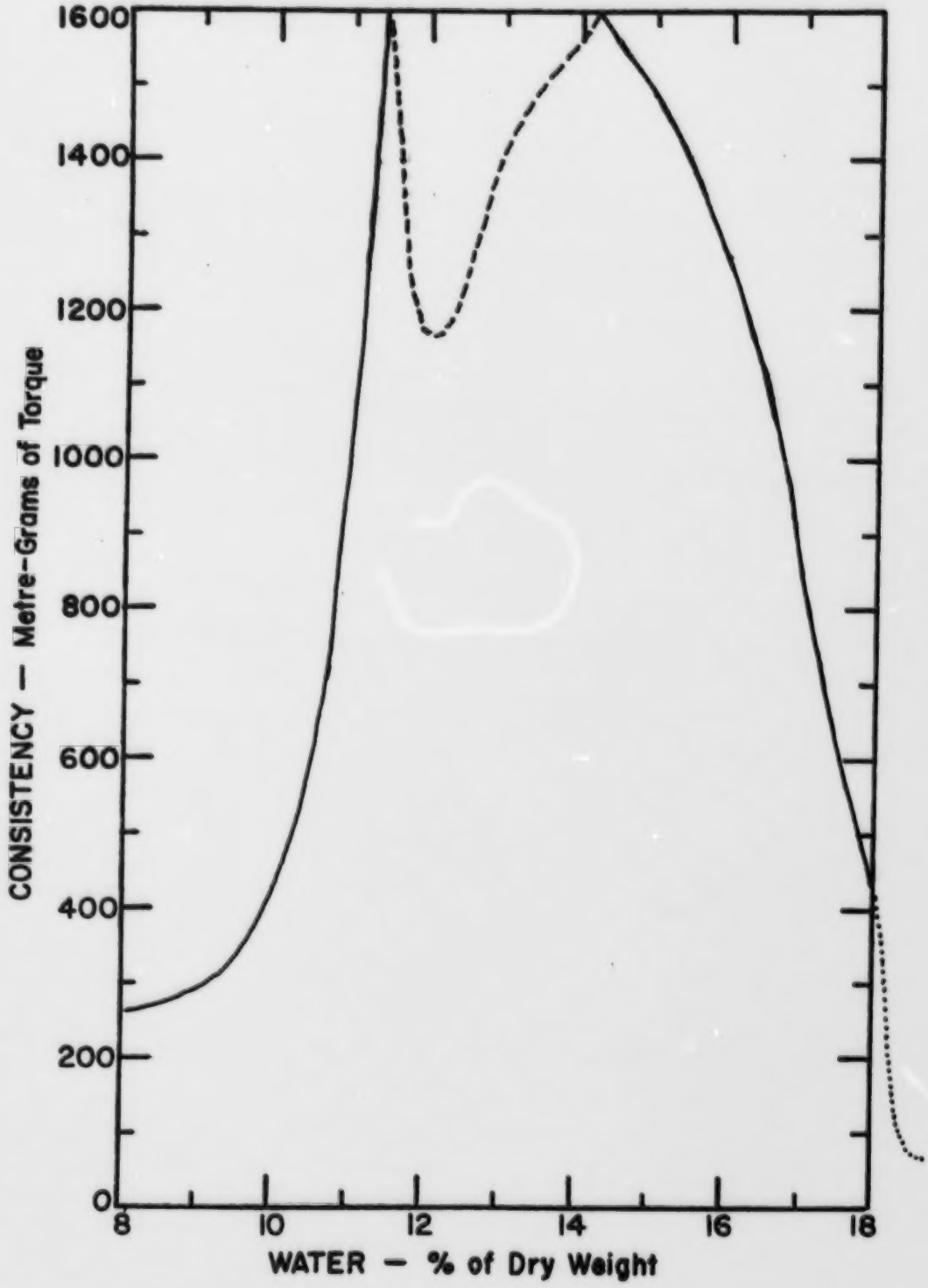

Fig. 7. Plastogram of test batch #10 (Zircon/Mullite).